DISTRIBUTION OF AQUATIC INSECTS IN A SMALL STREAM IN NORTHWEST HIMALAYA, INDIA[1]

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Key words: Northwest Himalaya, stream insects, species composition, microhabitat, species diversity index.

This article deals with species composition, annual variability, microhabitat preference and species diversity index of aquatic insects in a perennial stream in northwest Himalaya, during 1989-91. A total of 62 morphospecies belonging to Ephemeroptera, Odonata, Plecoptera, Hemiptera, Megaloptera, Coleoptera, Trichoptera and Diptera were caught in the samples. Some of these showed a marked preference for particular microhabitats within a short span of the stream. Nymphs of mayflies, *Baetiella tuberculata* (Kazlauskas) and *Baetiella* sp., and the larvae of dipteran *Horaia* sp., preferred stony substrate with fast water current. Burrowing nymphs of mayfly *Caenis* sp., and the stoneflies *Amphinemura rahungi* Aubert and *Nemoura* sp., predominated in sand and silt deposited between gravel and rubble. Nymphs of *Ecdyonurus, Epeorus* and *Ephemerella* (Ephemeroptera) were mainly associated with gravel-rubble and also loose stones. Filter feeders, like larvae of *Cheumatopsyche columnata* Martynov (Trichoptera) and some species of *Simulium* (Diptera) were abundant in the gravel-rubble as it provided suitable substratum for attachment of their nets and bodies. The gerrid bugs *Chimarrhometra orientalis* (Distant) and *Metrocoris compar* (Buchnan White), and the gyrinid beetle *Orectochilus murinus* Regimbart, were mainly found in sheltered midstream pools by the side of large rocks. Mean monthly species diversity index varied little between two years, i.e. 2.13 and 2.66 for 1989-90 and 1990-91 respectively.

INTRODUCTION

The stream environment is complex and heterogeneous, having many habitat patterns, primarily due to a wide range in the size of substrate particles and configurations on the stream bed, different kinds of microcurrents and a variety of available food. These habitats are characterised by a high diversity of aquatic insects. There are considerable differences in insect distribution between various sections along the course of a stream and also at microhabitat level (Williams and Feltmate 1992). Considerable information is available on the distribution and other ecological aspects of stream insects in Europe and North America, as reviewed by Hynes (1970), Resh and Rosenberg (1984), and Williams and Feltmate (1992). Flowers (1991) has dealt with the insect diversity of Central American rivers. But such studies on Indian stream insects are sparse and limited to the works of Annandale and Prashad (1919), Gupta and Michael (1983), Julka *et al.* (1988), Arunachalam *et al.*(1991), Balasubramanium *et al.* (1992) and Burton and Sivaramakrishnan (1993).

The objective of this investigation was to study species composition, annual variability, specific niche preference, and species diversity index of insects in a stream in northwest Himalaya.

STUDY AREA

Himachal Pradesh (between 30°23'-33°12' N lat., 75°37'-79°04' E long.) falls in the northwest Himalaya. The entire area is drained by an intricate network of springs, streams and rivers. A spring-fed perennial stream in the Barog Hills (Dist. Solan) was selected for the

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present study. It flows southeastwards to discharge into the Raboun tributary of the Giri-Yamuna drainage. The area has four distinct seasons: spring (late February to April), summer (May to August), autumn (September to middle of November) and winter (middle of November to middle of February). A distinct wet summer period during the southwest monsoon months of July-August is distinguished from summer in May-June. Total rainfall during 1989-90 and 1990-91 was 1404.7 mm and 993.4 mm respectively.

The study area is a small riffle close to the source of the stream near Barog railway station (7 km from Solan; altitude 1500 m above msl. 30°55 'N lat; 77°06 'E long.). The riffle is 0.5-2.6 m wide and 5-15 cm deep. It flows through a narrow valley, largely exposed to sunlight. Its substrate comprises gravel, rubble and boulders, and granite rocks. A considerable amount of sand is deposited in the interstices of gravel and rubble. Various physico-chemical characteristics of the stream are given in Table 1.

Riparian vegetation comprises trees of *Pinus roxburghii*, *Eucalyptus* sp., *Quercus leucotrichophora*, *Morus alba* and *Pristacia intergrimma*; small shrubs like *Utrica dioco*, *Pinsepia utilis*, *Rubus ecipticus* and *Carrisa caranda*. Prominent herbs on the banks of the stream are *Targetes minuta*, *Ipomea* sp. and *Salvia lanata*.

Table 1
PHYSICO-CHEMICAL CHARACTERISTICS OF A STREAM AT BAROG (H.P.)

Characteristic	Range	Average
Current velocity (m s^{-1})		
Rocky substratum	0.27 - 1.45	0.71 (±0.31)
Gravel-rubble/loose stone substratum	0.37 - 1.08	0.47 (±0.18)
Flow (cm^3 s^{-1})		
Rocky substratum	8.50 - 114.70	38.00 (±30.43)
Gravel-rubble/loose stone substratum	9.90 - 93.50	30.06 (±24.81)
Surface temperature (°C)	10 - 25	16.60 (± 4.98)
Dissolved oxygen (mg l^{-1})	2.52 - 10.70	4.99 (± 1.61)
Free carbon dioxide (mg l^{-1})	0 - 6	0.74 (± 1.59)
Total alkalinity (mg l^{-1})	96.75 - 125.00	114.21 (± 6.94)
Specific conductivity (u mhos)	25 - 96	33.85 (± 5.09)
pH	7.8 - 8.5	7.99 (± 0.20)
CPOM (mg m^{-2})	0.63 - 12.84	3.28 (± 0.17)
FPOM (mg m^{-2})	1.33 - 59.50	15.38 (± 1.01)

Material and Methods

The benthos were sampled monthly by quantitative and semiquantitative methods from June, 1989 to May, 1991. Different microhabitats arising from physical changes in the substratum of the riffle were sampled: Site I with rocky bottom, Site II with gravel, Site III with loose stones and Site IV comprised small midstream pools with slow flow of water. Semiquantitative samples were obtained by operating a hand net (30 cm diam., cloth mesh 0.4 mm) for about 45 seconds in each of three pools, and by picking and washing 20 loose stones (diam. 15-20 cm). Quantitative samples were taken with a Surber's sampler (25 cm^2 area; mesh opening — 0.4 mm) at places with almost level rocky and gravel strata. The Surber's sampler was operated by the method of Welch (1948). On each occasion, 6 replicates were obtained. The area sampled exceeded 0.3 m^2, which is considered satisfactory for normal quantitative purposes by Dudgeon and Richardson (1988).

The water surface temperature was taken with a standard mercury celsius thermometer. Current velocity was determined by timing a float in midcurrent. The volume of flow, dissolved oxygen, carbon dioxide and total alkalinity were estimated by methods given in Welch (1948). The pH was recorded with a pH meter (Model AMK 1020A AMKAY) and conductivity readings were taken with a conductivity meter. The coarse particulate organic matter (CPOM; >1mm) and fine particulate organic matter (FPOM; <1mm) were estimated following the methods in Ernst and Stewart (1986).

OBSERVATIONS

Faunal composition

In all, 62 morphospecies of insects were collected from the Barog stream during the sampling period. These belonged to 8 major groups: Ephemeroptera, Odonata, Plecoptera, Hemiptera, Megaloptera, Coleoptera, Trichoptera and Diptera. Relative densities of major groups at four sites are shown in Table 2. Ephemeroptera, Trichoptera and Diptera were co-dominant on the rocky substratum and in gravel/rubble section. Among nondominant groups, only Coleoptera and Plecoptera had a significant presence in gravel-rubble. The insect fauna on loose stones was dominated by the larvae of Trichoptera, followed by Diptera and Ephemeroptera. Dominant insect groups in midstream pools were semiaquatic Hemiptera on the water surface and Coleoptera in the water column. Larvae of Ephemeroptera, Trichoptera and Diptera were also present in significant numbers.

Annual variability

The number of taxa varied little over the two years of the present studies (Table 3). However, relative densities of numerically dominant (>1% of the total number collected) species of the mayflies *Baetis*, *Ecdyonurus* sp.1 and *Epeorus*, the stonefly *Nemoura*, and the blackfly *Simulium* (*Simulium*) *digitatum* and *Simulium* (*Simulium*) sp. increased significantly from the first (1989-90) to second year (1990-91). On the contrary, these values declined substantially from first to second year in case of chironomids like *Pentaneura* sp., *Cryptochironomus* sp., and trichopterans like *Agapetus triangularis* and the Lepidostomatidae.

Variability between sites

Relative densities of all morphospecies at different sites are presented in Table 3. Within Ephemeroptera, *Baetis* sp. 1 attained greatest abundance on rocky substratum (34.43%) and in gravel/rubble (16.19%) sections of the riffle. *Baetiella tuberculata* and *Baetiella* sp. were

TABLE 2
RELATIVE DENSITY (%) OF INSECT GROUPS IN A HILL STREAM AT BAROG IN 1989-90 AND 1990-91

Site	Rocky substratum		Gravel/Rubble substratum		Loose stones		Midstream pools	
	(Site I)		(Site II)		(Site III)		(Site IV)	
Order	1989-1990	1990-1991	1989-1990	1990-1991	1989-1990	1990-1991	1989-1990	1990-1991
Ephemeroptera	50.2	53.5	29.4	41.0	11.8	12.4	16.6	13.8
Odonata	-	-	0.7	0.4	-	0.1	-	-
Plecoptera	0.2	2.7	2.4	14.5	0.4	1.9	4.3	1.8
Hemiptera	0.2	0.1	0.3	-	-	-	27.9	30.2
Coleoptera	0.4	0.3	3.1	2.8	0.1	0.5	15.8	30.2
Trichoptera	28.8	23.6	40.2	18.5	76.5	68.8	16.2	10.2
Diptera	20.2	19.8	23.9	22.8	11.2	16.2	19.2	13.8

TABLE 3

RELATIVE DENSITY (%) OF INSECTS IN A STREAM AT BAROG FOR 1989-90 AND 1990-91, AND AT FOUR SITES FOR 1989-91 (BOTH YEARS COMBINED).

Taxon	1989-90	1990-91	1989-91			
			Rocky Site I	Gravel-Rubble Site II	Loose stones Site III	Midstream pools Site IV
Order EPHEMEROPTERA						
Baetis sp.1	13.87	19.25	34.43	16.19	5.00	7.96
Baetis sp.2	0.82	2.17	2.77	1.53	0.50	-
Baetiella tuberculata (Kazlauskas)	1.89	1.09	5.03	0.66	0.70	1.33
Baetiella sp.	1.40	1.50	4.30	0.73	0.82	0.88
Ecdyonurus sp.1	1.44	2.37	0.30	2.78	1.49	0.66
Ecdyonurus sp.2	1.25	1.00	0.13	1.45	1.43	0.22
Epeorus sp.	0.90	1.76	0.94	1.65	0.79	1.99
Ephemerella sp.1	0.84	0.35	0.30	0.88	0.47	0.22
Ephemerella sp.2	0.79	1.20	0.67	1.53	0.32	0.22
Ironopsis sp.	0.25	0.01	0.64	0.03	0.03	-
Choroterpes (*Euthraulus*) sp.	0.39	0.29	0.34	0.41	0.29	0.22
Caenis sp.	3.68	3.50	1.45	6.53	0.23	1.99
Ephemera remensa Eaton	0.05	0.03	-	0.07	0.06	-
Order DIPTERA						
Simulium (*M.*) *ghoomense* Dutta	0.39	0.98	0.34	0.83	0.50	1.33
Simulium (*S.*) sp.	1.02	2.41	1.92	1.97	1.05	0.22
Simulium (*S.*) *digitatum* Puri	0.82	3.04	3.15	1.32	1.41	4.42
Simulium (*N.*) sp.	0.11	0.20	0.16	0.12	0.09	1.11
Simulium (*S.*) *himalayense* Puri	0.51	0.98	0.60	0.74	0.61	1.99
Simulium (*S.*) *rufibasis* Brunetti	0.05	0.11	-	0.10	0.12	-
Pentaneura sp.	3.22	1.89	0.51	4.69	0.76	0.88
Diamesa sp.	1.55	1.78	1.49	1.79	1.38	2.88
Cryptochironomus sp.	2.89	1.78	2.17	2.87	1.76	2.43
Microtendipes sp.	5.11	5.08	8.65	4.55	4.13	1.33
Pseudochironomus sp.	0.81	0.38	0.09	0.81	0.73	0.22
Palpomyia sp.	0.41	0.03	-	0.49	-	0.22
Atrichopogon sp.	0.05	0.01	0.09	0.05	-	-
Forcipomyia sp.	0.01	0.00	-	0.02	-	-
Horaia sp.	0.02	0.00	0.09	-	-	-
Blepharocera indica Brunetti	0.00	0.09	0.04	0.07	-	-
Telmatoscopus livingstoni Ipe & Kishore	0.02	0.00	-	0.02	-	-
Psychoda alternata Say	0.01	0.00	0.04	-	-	-
Pericoma kothiensis Ipe & Kishore	0.01	0.00	-	0.02	-	-
Atherix sp.	0.34	0.85	0.21	1.05	0.03	0.22
Antocha sp.	1.08	0.40	0.21	1.01	0.85	0.22
Holorusia sp.	0.01	0.00	-	0.02	-	-
Hexatoma sp.	0.08	0.00	-	0.10	-	-
Tabanus sp.	0.68	0.14	0.09	0.87	0.03	-
Dixa sp.	0.13	0.03	-	0.10	0.03	0.88
Order TRICHOPTERA						
Agapetus triangularis Martynov	28.27	23.37	19.39	15.67	51.83	3.54
Lepidostomatidae	12.41	3.24	2.85	7.27	13.85	9.51
Rhyacophila sp.	0.19	0.03	0.30	0.10	0.06	-
Chimarra aberrans Martynov	0.17	0.50	0.38	0.25	0.43	0.22

TABLE 3 (*contd.*)
RELATIVE DENSITY (%) OF INSECTS IN A STREAM AT BAROG FOR 1989-90 AND 1990-91, AND AT FOUR SITES FOR 1989-91 (BOTH YEARS COMBINED).

Taxon	1989-90	1990-91	1989-91 Rocky Site I	Gravel-Rubble Site II	Loose stones Site III	Mid stream pools Site IV
Stenopsyche sp.	0.14	0.24	-	0.32	0.12	-
Hydroptilidae	0.01	0.03	0.04	-	0.03	-
Polycentropodidae	0.39	0.37	0.13	0.26	0.85	-
Cheumatopsyche columnata Martynov	5.13	6.05	2.98	6.75	5.77	1.33
Order PLECOPTERA						
Nemoura sp.	1.10	6.55	1.11	6.05	0.88	2.88
Amphinemura rahungi Aubert	0.05	1.37	0.09	1.25	0.05	-
Neoperla sp.1	0.38	0.18	0.64	0.26	0.09	0.67
Neoperla sp.2	0.22	0.18	0.47	0.19	0.09	-
Order COLEOPTERA						
Elmidae	1.31	0.55	0.13	1.86	0.12	0.45
Orectochilus murinus Regimbart	1.03	1.29	0.04	0.85	0.15	18.58
Dineutus (P.) indicus	0.01	0.00	-	-	-	0.22
Psephanoides gahani Champion	0.04	0.25	0.17	0.20	0.03	-
Order HEMIPTERA						
Chimarrhometra orientalis (Distant)	1.12	0.33	-	0.02	-	20.58
Onychotrechus robustus Anderson	0.00	0.01	-	-	-	0.22
Metrocoris compar (Buchnan White)	0.26	0.25	0.13	0.03	-	5.98
Enithares sp.	0.00	0.01	-	-	-	0.22
Micronecta sp.	0.19	0.01	-	0.07	-	1.56
Order ODONATA						
Baydera indica (Selys)	0.01	0.03	-	0.02	0.03	-
Gomphidae	0.32	0.14	-	0.51	-	-
Order MEGALOPTERA						
Corydalus sp.	0.01	0.01	-	0.02	-	-
Total number of taxa	59	54	44	56	44	38

present in significant numbers on rocky substratum, while *Caenis* sp. was frequent in gravel-rubble. *Ecdyonurus* spp. were generally associated with gravel-rubble and loose stones.

The distribution and abundance of chironomids varied greatly between the sites: *Microtendipes* sp. and *Cryptochironomus* sp. were abundant on rocky and gravel-rubble substrate, and among loose stones, while *Pentaneura* sp. was numerous in gravel-rubble. The simulid, *Simulium (S.) digitatum* attained abundance on rocky substratum in midstream pools. Families Blepharoceridae (*Horaia* sp.; *Blepharocera indica*), Psychodidae (*Telmatoscopus livingstoni*; *Psychoda alternata*; *Pericoma kothiensis*) and Tipulidae (*Holorusia* sp. and *Hexatoma* sp.) were largely confined to rocky substratum or gravel-rubble section of the riffle.

Among Trichoptera, *Agapetus triangularis* (51.83%) and *Cheumatopsyche columnata* (6.75%) were abundant on loose stones with significant numbers on rocky substratum and in gravel-rubble. Likewise, the representatives of Lepidostomatidae (13.85%, 7.27%) predominated among loose stones and in gravel-rubble, but also with significant numbers in midstream pools. *Chimarra aberrans* were collected from all 4 sites, although at low densities. *Rhyacophila* sp. and members of Poly-centropodidae were not found in midstream pools.

Among other insect groups, the stonefly *Nemoura* sp. was more abundant in gravel-rubble than in other sites. The gyrinid beetles (*Orectochilus murinus*) and the gerrid Hemiptera (*Chimarrhometra orientalis*; *Metrocoris compar*) preferred midstream pools.

TABLE 4

INDICES OF SPECIES DIVERSITY (H') OF INSECTS DURING DIFFERENT MONTHS IN A STREAM AT BAROG (H.P.) 1989-1991 (BOTH YEARS COMBINED)

Month	Index of species diversity (H')	
	1989-90	1990-91
Jun.	2.30	2.30
Jul.	N.R.	2.62
Aug.	2.40	2.30
Sep.	2.37	2.45
Oct.	2.55	2.18
Nov.	2.39	1.90
Dec.	2.10	2.38
Jan.	1.91	1.91
Feb.	1.81	2.19
Mar.	1.93	1.76
Apr.	1.43	2.34
May	2.25	2.77
Mean annual	2.13	2.26

N.R. = Not recorded

Species diversity index

Species diversity indices (H') for different months are depicted in Table 4. Quantification of species diversity index indicated generally higher values from summer to autumn (May to October). Lower values were recorded in late winter and spring months (January to April) during the first year, and in November, December and March during the second year. A peak diversity index of 2.55 occurred in October and 2.77 in May during the first and second years respectively. Minimum diversity index of 1.43 was obtained for April, 1990, and it was 1.76 for March, 1991. The mean monthly species diversity indices varied little between two years i.e. 2.13 and 2.66 during the first and second years, respectively.

DISCUSSION

From the available data, the stream under study can be described as an Ephemeroptera-Trichoptera-Diptera type. This type of aquatic insect community, also represented by Plecoptera and Coleoptera, appears to be characteristic of streams with gravel and rubble in both tropical and temperate regions (Bishop 1973; Minshall and Kuehne 1969; Clifford 1978; Gupta and Michael 1983).

Certain species indicated a preference for microhabitats within a short span of the stream. Substrate type influenced their distribution the most, which is consistent with the observation of Arunachalam *et al.* (1991) on the invertebrates of a south Indian river. Nymphs of the mayflies *Baetiella tuberculata* and *Baetiella* sp. (Family Baetidae) were abundant at Site I with rocky substrate and rapid water current, while the dipteran larvae of *Horaia* sp. (Family Blepharoceridae) were restricted in occurrence. They displayed obvious morphological modifications for adaptation to rocky substrate to withstand the force of rapid currents. The abundance of *Baetiella* sp. at this site may be attributed to their streamlined bodies and sparsely fringed cerci, which provide the least resistance to the rapid water current. In addition, their claws are dentate for clinging to rocky surfaces. Their food includes algae growing on submerged rocky substrate which is available in plenty at this site. The preference of *Baetiella* for rocky substrate with a fast current has also been demonstrated by Dudgeon (1990) in Hongkong streams. To withstand the force of water current, larvae of *Horaia* sp. are provided with 6 median ventral suction discs which function efficiently only on rocky surfaces.

Site II of the stream is a mixed substrate section comprising gravel, rubble, coarse sand particles and silt. It provides many microhabitats and therefore supports a greater variety of taxa (56 species; Table 3).

Immature stages of several benthos had also higher densities in gravel-rubble section than in other microhabitats e.g. *Ecdyonurus* sp.1, *Epeorus* sp., *Ephemerella* spp. and *Caenis* sp. among mayflies; *Nemoura* sp. and *Amphinemura rahungi* among stoneflies; elmid beetles; *Pentaneura* sp. and *Palpomyia* sp. among dipterans. Nymphs of *Caenis* are adapted to burrowing in coarse particles, sand and silt, and possess a large second pair of gills which are operculate and protect succeeding gills from becoming clogged with silt. Their abundance in gravel-rubble is due to their adaptation to live in silt and coarse sand particles deposited between gravel and rubble, which also provides them a sheltered microhabitat. Cummins and Lauff (1969) also found that light silting enhanced the selection of interstices of coarse sediments by *Caenis latipennis*. However, Bishop (1973) suggested that microdistribution of *Caenis* sp. was due to food availability and habitat stability rather than a particular substrate. Like *Caenis* sp., nymphs of *Nemoura* sp. and *Amphinemura rahungi* also burrow in coarse particles among gravel-rubble, for protection from predators.

The nymphs of *Ecdyonurus* sp.1, *Epeorus* sp. and *Ephemerella* spp. have flat bodies which appear to be an adaptation to decrease resistance to water current, and also to enable them to seek shelter in crevices and under stones. High density of dorsoventrally flattened nymphs of the mayfly *Habrophlebia vibrans* has also been correlated with the presence of gravel in a Canadian stream (Lauzon and Harper 1988). The bodies of the elmid beetle larvae and the chironomid *Pentaneura* sp. are long, slender and flexible, and allow easy passage among gravel and rubble. They seek out this type of microhabitat as a refuge, and also to exploit micronutrients trapped among substrate particles (Williams and Feltmate 1992).

The case-building caddisfly larvae of *Agapetus triangularis* of the family Glossosomatidae and representatives of the family Lepidostomatidae were predominant among loose stones in the gravel-rubble zone. Their abundance is possibly due to the presence of mineral and organic matter required for case building, and also protection against water current. In the rocky zone, they were lower in number because of fast water current (i.e. mean 0.71 m s^{-1} against mean 0.46 m s^{-1} in gravel-rubble section), and less amount of mineral and organic matter. A few workers have also related the abundance of case-building caddisfly larvae with the availability of material for their case construction. According to Tolkamp (1980) *Sericostoma personatum* uses mainly 0.25-0.50 mm grains of minerals for its case, and it prefers to live on predominantly coarse substrate. Similarly, the larvae of *Pycnopsyche scabripennis* prefer substrates where suitable materials for their cases are present (Mackay 1977). Net spinning larvae of the trichopteran *Cheumatopsyche columnata* were more common in the gravel-rubble zone than at other sites. Possibly, this microhabitat provided suitable substrate to attach their nets for trapping food particles flowing with slow water current. Larvae of some *Simulium* spp., well known filter feeders, were also more abundant in the gravel-rubble zone than elsewhere, because of the availability of suitable substrates (stones) for their attachment and a rich supply of FPOM (mean 15.375 mg m^{-2}).

Chimarrhometra orientalis, *Onychotrechus robustus* and *Metrocoris compar* (Gerridae: Hemiptera) and *Orectochilus murinus* (Gyrinidae: Coleoptera) showed preference for midstream pools usually formed by the side of bigger rocks. They are able to avoid the force of water current in this microhabitat. Similarly, Williams and Feltmate (1992) found these in abundance in such a habitat where the water current was of less intensity. However, the young stages of Gerridae and Gyrinidae occupied different ecological zones, the former midstream pools and the latter gravel section.

Seasonal changes in species diversity were evident during both years. Low values of diversity indices (H') occurred in late winter and spring during the first year. Unfavourable climatic conditions probably caused depressed winter values. Rosillon (1985) also recorded lower winter values in a Belgian chalk trout stream, but with less evident seasonal changes in species diversity. In Barog stream, mean annual species diversity indices of 2.13 and 2.26, during the first and second years respectively, were slightly lower than 2.44 as recorded by Rosillon (1985). However, Burton and Sivaramakrishnan (1993) reported higher values of species diversity (H'), ranging from 3.86 to 4.41, in a wet evergreen forest stream of the Silent Valley National Park, southern India.

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